

METHOD AND APPARATUS FOR SEPARATING IMMISCIBLE PHASES WITH DIFFERENT DENSITIES

Reference to Related Application

5 **[0001]** This application claims the benefit under 35 U.S.C. §119 of
U.S. patent application No. 60/463,783 entitled “**METHOD AND
APPARATUS FOR SEPARATING FOUR IMMISCIBLE PHASES
WITH DIFFERENT DENSITIES**”, which is incorporated herein by
reference.

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Technical Field

[0002] The invention relates to methods and apparatus for
separating immiscible phases having different densities. Embodiments of
the invention have application in the oil industry. The invention has
15 application in separating materials such as oil, natural gas, water and
solids, such as sand.

Background

[0003] In the oil industry it is often necessary to separate oil from
20 water and other materials. For example, oil from an oil well may be
mixed with water and may have entrained in it gases, such as natural gas
and/or solids, such as sand. It is necessary to separate these phases.
Separators are used for this purpose. Some such separators are known as
“free water knockout devices”. Such separators typically rely merely on
25 the force of gravity for separation. Gravity separators can be either
vertical or horizontal in configuration.

[0004] In vertical skimmers, oil droplets rise upward countercurrent to the downward flow of water. In horizontal separators oil droplets rise perpendicular to the flow of water. Horizontal separators tend to be more efficient at treating water because the oil droplets do not have to flow
5 countercurrent to the flow of water. However, horizontal vessels often cannot handle effectively gas surges or deposits of sand and other solid particles.

[0005] To increase the ability of separators to handle small particles
10 of oil, it is typical to heat the fluid being treated to elevated temperatures. Heating the fluid lowers its viscosity and enhances separation. Due to large flow rates a significant amount of energy is required to heat the fluid. Providing this heat energy is expensive, especially at times when energy prices are high. Furthermore, the pre-heaters used to heat fluids
15 for separation have a significant capital cost and require frequent maintenance and repairs.

[0006] In order to improve separation efficiency, prior art devices are made to provide increased residence time. This inevitably increases
20 their sizes and construction costs.

[0007] The high content of oil in the effluent is another important disadvantage of existing free water knockout devices. A certain amount of oil contained in the effluent is carried away when the effluent is
25 re-circulated to the well. Over time, such oil losses can be far from negligible.

[0008] Furthermore, oil pumped back into the well tends to accumulate in the ground, gradually obstructing the passage of water utilized for oil extraction. As a result, the well could be plugged and put out of service prematurely with significant losses.

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[0009] Additionally, inadequate separation of water and solids from oil may result in the oil failing to meet specifications for transporting the oil in a pipeline.

10 **[0010]** Various methods for enhancing separation by means of plate coalescers have been devised. Prior art coalescers are commonly called parallel plate interceptors (PPI) corrugated plate interceptors (CPI), or cross flow separators. In PPI's, sediments migrate inwardly and downwardly to the bottom of the separator where they are removed.

15 Because of the design of the PPI's the collection of sediments is inadequate resulting in frequent plugging of the device.

[0011] CPI's have parallel plates which are corrugated with the direction of the corrugations parallel to the direction of the flow. The

20 plate pack is inclined at an angle of 45° to allow both oil and sand to separate. Experience has shown that oily wet sand may adhere to a 45° slope clogging the plates. In addition, the sand collection channels cause turbulence and are themselves subject to plugging.

25 **[0012]** In cross-flow devices liquid flows perpendicular to the direction of the corrugations in the plates. This allows the plates to be held at a steeper angle to facilitate sediment removal. However, in typical

cross flow devices the plates are held within a cylindrical tank. In such devices the sediment collection zone is inadequate and the length of the plates is limited by the diameter of the tank.

- 5 [0013] Despite the various kinds of separators available, there is a need in the oil industry for cost effective separation devices which are capable of separating phases such as oil, gas, solids and water.

Brief Description of the Drawings

- 10 [0014] In drawings which illustrate apparatus and methods according to non-limiting embodiments of the invention:

Figure 1 is an elevational section through an apparatus according to one embodiment of the invention;

- 15 Figure 2 is a sectional view along line 1-1 showing a plates pack of the apparatus of Figure 1;

Figure 3 is an elevational section through the fine-separation chamber of the apparatus of Figure 1;

Figure 4 is an elevational section showing the polishing chamber of the apparatus of Figure 1;

- 20 Figure 5 is a sectional view along line 2-2 of the polishing device of Figure 4;

Figure 6 is a block diagram illustrating a separation process achieved in several steps according to another embodiment of the invention.

Description

[0015] Throughout the following description, specific details are set forth in order to provide a more thorough understanding of the invention. However, the invention may be practiced without these
5 particulars. In other instances, well known elements have not been shown or described in detail to avoid unnecessarily obscuring the invention. Accordingly, the specification and drawings are to be regarded in an illustrative, rather than a restrictive, sense.

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[0016] Figure 1 shows an apparatus **200** for separating a mixture of a less dense fluid such as oil, a more dense fluid such as water, solids and possibly gas according to a specific embodiment of the invention.

Apparatus **200** has a number of inventive features which may be

15 combined as in apparatus **200** or may be implemented separately. While these features are implemented in a specific manner in apparatus **200** they may also be implemented in other functionally equivalent manners without departing from the invention. The methods of the invention are described herein in the context of the operation of apparatus **200** being
20 used for separating oil from water, gas and solids phases. The methods of the invention may also be practiced using apparatus which differs in details of construction from apparatus **200**.

[0017] Apparatus **200** comprises a vessel **10**. In the illustrated
25 embodiment, vessel **10** is cylindrical and is supported horizontally on legs **11**. Domed end plates **10a** and **10b** close either end of vessel **10**. A mixture of fluids and solids to be separated is passed through vessel **10** in

a direction from end plate **10a** to end plate **10b**. Throughout the following description, the direction from end plate **10b** to end plate **10a** is referred to as “forward”, and the direction from end plate **10a** to end plate **10b** is referred to as “rearward”.

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[0018] Plate **10a** has a centrally located aperture **12**. Aperture **12** provides fluid communication between vessel **10** and distribution chamber **20**. Distribution chamber **20** is defined by a cylindrical housing projecting from vessel **10**. Distribution chamber **20** is closed by a lid **22**
10 which is bolted to a flange **21**. A coalescing plates pack **30** is located in aperture **12**. Plates pack **30** comprises a number of corrugated plates. An aperture located above plates pack **30** permits oil and gas retained by plates pack **30** to rise into a collection zone **110**. The aperture is a rectangular slot **30b** in the illustrated embodiment.

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[0019] The lower portion of distribution chamber **20** is cut out below plates pack **30** to allow solids to fall freely into collection zone **40**. Sediments may be evacuated from space **40** through a drain line **40a** which can be connected to a vacuum truck. This may be done
20 periodically. A conduit **24** in a lower portion of distribution chamber **20** provides a way to drain distribution chamber **20** when required.

[0020] A fluid comprising a mixture of phases to be separated can be introduced into distribution chamber **20** by way of an inlet line **23**.
25 Distribution chamber **20** ensures even distribution of the fluid (which

includes a mixture of phases) through plates pack **30** and significantly reduces the velocity of the fluid entering the apparatus from inlet line **23**.

[0021] As shown in Figures 1 and 2, a circular plate **32** affixed to the inner walls of the distribution chamber **20** in the way of aperture **12** partially closes distribution chamber **20**. Plate **32** has a square-shaped opening **32a** whose vertical axis is rotated by 30° from the horizontal. The rotation is counterclockwise in the illustrated embodiment. Plate **32** supports the fore end of plates pack **30** and directs the fluid entering distribution chamber **20** into plates pack **30**.

[0022] A baffle plate **31**, which can be generally circular in shape is affixed to the aft end of distribution chamber **20**. Baffle plate **31** partially encloses the front end of vessel **10**. A lower portion of baffle **31** forms space **40** in conjunction with the walls of vessel **10**. An upper portion of baffle **31** deflects oil and gas separated within plates pack **30** towards an oil collection zone **110** of vessel **10** for further separation.

[0023] Baffle plate **31** has a square-shaped aperture **30a** situated in its mid-section. Aperture **30a** is rotated clockwise by 30° from the horizontal. Aperture **30a** is suitably sized to accommodate the aft end of plates pack **30**.

[0024] Plates pack **30** is held together by a cage **33** which is secured to circular plate **32** by means of brackets **34**, as shown in Figure 2. The plates of plates pack **30** are preferably equally spaced apart. Plates

pack **30** directs oil and solids to collection zones **110** and **40** respectively. As the mixture of oil, water and solids is separated by apparatus **200**, an oil pad forms in an upper region of vessel **10** comprising oil collection zones **110**, **111** and **112**. Plates pack **30** is situated in the space between
5 circular plate **32** and baffle plate **31**. A fore end of plates pack **30** is supported by circular plate **32** and an aft end of plates pack **30** is supported by baffle plate **31**.

[0025] In this embodiment, the corrugated plates of plates pack **30**
10 are inclined at 60° to the horizontal. This facilitates the migration of solids to collection zone **40** and prevents undue deposits from accumulating on the surface of the corrugated plates. At the same time, the steep angle of inclination ensures effective migration of any oil retained by the plates toward oil collection zone **110**. The corrugations
15 of plates pack **30** are oriented so that they cross the direction of flow of fluid through plates pack **30**. This reduces the impact of gas surges and creates a quiet zone that assists separation.

[0026] As shown best in Figure 3, vessel **10** comprises a fine
20 separation stage designed for fine separation. The fine separation stage is housed within a generally cylindrical fine separation chamber **50** and is placed eccentrically to the axis of vessel **10**. Chamber **50** of fine separation stage is supported by baffle **61**, baffle **62**, and baffle **71**.

25 [0027] Baffles **61** and **62** are generally circular plates. The upper portions of baffles **61** and **62** are cut out. Baffles **61** and **62** are affixed to the inner walls of vessel **10**. Openings are provided between the upper

edges of baffles **61** and **62** and the upper section of vessel **10**. Baffles **61** and **62** have generally circular apertures therein to permit chamber **50** to pass therethrough. The axis of the apertures of baffles **61** and **62** are situated eccentrically to the longitudinal axis of vessel **10**. Baffles **61** and **62** direct fluid to flow primarily through fine-separation chamber **50**. In use, an oil pad forms above baffles **61** and **62**. The oil pad blocks the passage of water over the edges of baffles **61** and **62**.

[0028] The fore end of chamber **50** is partially enclosed by a plate **51**. Housing **50** is in fluid communication with the lower section **41** of vessel **10** through an aperture (rectangular opening **52**) at the lower side of housing **50**. A perforated plate **51a** distributes the flow to a screw **53** situated between plate **51a** and a coalescing chamber **54**.

15 [0029] Screw **53** causes fluid flowing through housing **50** to flow in a helical path. As fluid travels along screw **53**, it ascends and descends several times leaving behind oil droplets when it reaches upper portions of screw **53** and fine sediments at the lower portions of screw **53**.

Apertures comprising upper and lower slots **57** and **58** located in the upper and lower parts of housing **50**, respectively, between the flights of screw **53** permit oil and sediments to exit from housing **50**. Upper slots **57** release oil reclaimed from the fluid into oil collection zones **111** and **112**. Lower slots **58** discharge fines removed from the fluid into collection zones **42** and **43**.

[0030] At the end of screw **53** is a first coalescing chamber **54**, which is defined between plates **54a** and **54b**. Plates **54a** and **54b** may be affixed to the inner wall of housing **50** forming a generally cylindrical coalescing chamber **54**. Plate **54a** is perforated at its lower portion
5 whereas plate **54b** is perforated at its upper section. Coalescing chamber **54** is in part filled through meshed openings **54c** with free-floating oleophilic beads which are less dense than water. Meshed openings **54c** may be covered once the beads have been inserted into coalescing chamber **54**. The flow of liquid is directed by screw **53** to the lower
10 portion of coalescing chamber **54** through the perforations in plate **54a**. Upon entering coalescing chamber **54**, the fluid travels upwards between the oleophilic beads, which attract small oil droplets through surface tension forces. The fluid leaves coalescing chamber **54** through the perforations of plate **54b**, which are sized to retain the beads in chamber
15 **54**. Oil is retained by the beads in the form of droplets which are released when the buoyancy of the droplets exceeds the forces of attraction exerted by the beads on the droplets. Released oil droplets are discharged into oil collection zone **112** through apertures **57**.

20 [0031] Fluid which has passed out of coalescing chamber **54** through the perforations in plate **54b** passes into a portion of housing **50** which contains a second screw **55**. Screw **55** may be constructed similarly to screw **53** and is located within housing **50** between coalescing chamber **54** and a second coalescing chamber **56**.

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[0032] Coalescing chamber **56** is situated at the aft end of screw **55** and may be constructed in substantially the same manner as coalescing

chamber **54**. Coalescing chamber **56** further retains oil droplets that have passed through coalescing chamber **54**. Coalescing chamber **56** is defined between plates **56a** and **56b**. Plate **56b** has an upper perforated section which provides fluid communication between chamber **56** and a
5 polishing chamber **70**.

[0033] Small amounts of oil which coalesce within chamber **56** are released into the upper portion of polishing chamber **70** from where they can be evacuated through conduit **94**.

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[0034] Baffles **61** and **62** divide vessel **10** into three oil collection zones **110**, **111** and **112**. Oil retained in collection zone **110** migrates over the edge of baffle **61** leaving behind small water droplets. Oil then travels to collection zone **111** and from there, to collection zone **112**
15 becoming gradually drier.

[0035] A heating coil **120**, which may have a helical form, surrounds chamber **50** along its length. Coil **120** heats the oil accumulated in the upper portion of vessel **10** and thereby lowers the
20 viscosity of the oil. Heating coil **120** assists in the removal of water and solids from the accumulated oil. Because heating coil **120** is placed away from fine separation chamber **50**, and baffles **61** and **62** direct the flow into fine-separation chamber **50**, heat is not transferred directly to the liquid processed within chamber **50**. Thus, most of the liquid in chamber
25 **50** is heated only indirectly.

[0036] A plurality of ports **90**, **91**, **92** and **93**, which may comprise flanged conduits and may be similar to one another are provided in the upper portion of vessel **10**. Ports **90**, **91**, **92** and **93** accommodate instrumentation and controls.

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[0037] Oil accumulated at the upper portion of vessel **10** may be evacuated periodically through a conduit **92a** which extends towards the edge of baffle **62**. Conduit **92a** is surrounded by cup **92b** designed to create a smooth flow in order to prevent water from being entrained into conduit **92a**.

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[0038] Gas cylinder **100** extends upwardly from the upper section of vessel **10**. Gas cylinder **100** is made gas tight by a lid **102** bolted to a flange **101**. Gas cylinder **100** provides space for the accumulation of gas in vessel **10** and diminishes the effect of gas surges.

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[0039] Gas travels through the upper portion of vessel **10** to gas cylinder **100** from where it can be evacuated continually through conduit **103** which extends upwards well above the level of the liquid in order to minimize the risk of accidental entrainment of liquid into conduit **103**. Gas cylinder **100** may comprise a gas level sensor which monitors the level of the interface between the accumulated gas and the oil pad.

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[0040] Situated at the lower part of vessel **10** are drain conduits **41a**, **42a** and **43a**. These drain conduits may be used to evacuate fines collected at the bottom of vessel **10**.

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[0041] Polishing chamber **70** is best shown in Figures 1, 4 and 5. Polishing chamber **70** is defined between a baffle **71** and end plate **10b**. Baffle **71** comprises a circular plate affixed around its circumference to the inner walls of vessel **10**. Baffle **71** separates polishing chamber **70**
5 from oil collection zone **112**.

[0042] Plate **10b** has a generally circular aperture made concentrically with the axis of fine separation chamber **50**. Cylinder **72** is affixed to dome-shaped plate **10b** and comprises flange **73** and lid **74**
10 bolted to said flange in order to make polishing chamber **70** watertight. Polishing chamber **70** provides access to housing **50**. When lid **74** is removed, housing **50** can slide through the apertures of baffle **61**, baffle **62** and plate **10b** in order to be removed periodically for inspection.

15 [0043] At the upper section of polishing chamber **70** is an orifice connected to conduit **94**. Any small amounts of oil reaching polishing chamber **70** may be withdrawn through conduit **94** by opening a purge valve (not shown).

20 [0044] Polishing chamber **70** houses polishing device **80** designed to polish the water prior to discharging said water through outlet conduit **75a**. Referring to Figure 4 and Figure 5, polishing device **80** includes cylinder **80a**, which is partially enclosed at one end by a plate **83** affixed to cylinder **80a**. The aft end of cylinder **80a** is affixed to flange **81** and is
25 open. Cylinder **80a** is placed within cylinder **72** with flange **81** pressed against flange **73** of cylinder **72** by means of lid **74**. The aft end of polishing chamber **70** is therefore enclosed by lid **74**, which provides an

exit to the liquid processed within said polishing device. Lid **74** comprises an orifice connected to outlet line **76**. On the inner side of lid **74** is an arrangement devised to reduce turbulence and therefore undue entrainment of oil reclaimed by polishing device **80**. Semi-cylindrical
5 plate **75b** affixed to plate **75** forms chamber **75c** with a rectangular opening at its lower part.

[0045] The lower portion of cylinder **80a** is cut out to form an aperture, which may be rectangular, for the admission of liquid into
10 polishing stage **80**. Referring to Figure 4 and Figure 5, plate **84a**, plate **84b** and perforated plate **86** are affixed together and to plate **84** and are suitably curved to form coalescing chamber **82**. Stiffeners **87** affixed to plates **84a** and **84b** provide support to coalescing chamber **82** as the pressure drop through the fine coalescing beads could otherwise tend to
15 unduly distort chamber **82**.

[0046] Circular plate **83** affixed to cylinder **80a** encloses one side of coalescing chamber **82**. The other side of coalescing chamber **82** is enclosed by plate **88**, which extends downwards. The lower portion of
20 plate **88** is affixed to cylinder **80a** in order to separate coalescing chamber **82** from the outlet portion **89** of polishing device **80** and direct the incoming flow from section **44** to coalescing chamber **82**.

[0047] Perforated plate **84** encloses coalescing chamber **82** at the
25 lower portion of chamber **82**. Perforated plate **85** divides coalescing chamber **82** into two coalescing zones **82a** and **82b** filled with fine and coarse oleophilic beads, respectively. The orifices of perforated plate **84**,

perforated plate **85** and perforated plate **86** are suitably sized to retain the beads within coalescing chamber **82**.

[0048] Coalescing zone **82a** is filled with very small beads
5 designed to impede the passage of minute oil droplets that could not be retained by fine-separation cylinder **50**. Coalescing zone **82b** contains larger diameter beads, which process oil droplets released by coalescing zone **82a**. Larger oil droplets formed in coalescing area **82b** migrate upwards where they are retained in collection zone **80b** on the underside
10 of cylinder **80a** for periodic evacuation through conduit **76**.

[0049] Referring to Figure 1 and Figure 6, vessel **10** is initially filled with water to above the upper edge of baffle **61**. A gas cushion trapped in the upper section of vessel **10** creates a certain pressure within
15 vessel **10**. Mixture pumped to vessel **10** through inlet line **23** enters distribution chamber **20**. The relatively large space of distribution chamber **20** reduces suddenly the velocity of the fluid which is directed into plates pack **30** for preliminary separation. Rising oil droplets rise and reach the underside of a corrugated plate where they tend to
20 agglomerate. The inclination of the plate facilitates the migration of the oil droplets towards the upper edge of the plate. As adjacent oil droplets come in contact, they coalesce forming a larger droplet with enhanced buoyancy and tendency to leave the plates of plates pack **30**. After being released from plates pack **30**, the oil droplets travel toward oil collection
25 area **110**.

[0050] Because the flow is directed along the entire length of plates pack 30, the path of the fluid is prolonged which increases the probability of contact between oil droplets and the plates of plates pack 30. Furthermore, the fluid flowing over the corrugations has a sweeping effect over the surfaces of plates pack 30, which facilitates removal of accumulated oil from the plates.

[0051] Solids descend being retained by nearby corrugated plates of plates pack 30 and thus removed from the fluid. The steep angle of inclination combined with erosion by the flow of liquid prevents the formation of deposits. After removal from the fluid stream, solids migrate towards the designated collection area 40 where they accumulate over a certain period. Ample space below plates pack 30 accommodates accumulated solids which can be evacuated periodically.

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[0052] Gas enters distribution chamber 20 as bubbles of various sizes, which travel through plates pack 30 similarly to the oil droplets. Larger bubbles have an erosive impact on oil drops and solids adhering to plates thus preventing deposits. Small gas bubbles collide and attach themselves to oil droplets. Even very small bubbles have sufficient buoyancy for lifting oil droplets and thus removing said droplets from the liquid stream.

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[0053] Intersecting the axis of flow, the corrugations tend to impede the flow and reduce the impact of the gas surges creating a quiet zone that assists separation. Gas accumulates in gas cylinder 100 and in the upper portion of vessel 10 forming a cushion above the oil pad. The

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accumulation of gas is monitored by a pressure transmitter (not shown) which may, for example, be mounted on conduit **90**. A signal from the pressure transmitter controls, either directly or indirectly, the position of a valve (not shown) installed on conduit **103**. The pressure transmitter
5 actuates the valve in such fashion that the amount of gas released through conduit **103** by the valve is equal to the amount of gas entering vessel **10**, thus pressure in vessel **10** is maintained relatively constant.

[0054] It should be appreciated that the separation arrangement is
10 designed to tackle the problems posed by prior art devices because it ensures effective migration of oil and solids towards the collection zones, provides optimal conditions for separation and ample space for the collection of the separated phases.

15 [0055] Liquid exiting plates pack **30** moves downwards toward the lower portion **41** of vessel **10** and enters fine-separation chamber **50** through aperture **52**. The fluid subsequently flows in a helical pattern around screw **53**. The helical path followed by the fluid solves the problem posed by horizontal and respectively vertical separators. Thus,
20 oil no longer intersects the horizontal flow of water and can be recovered at the end of the ascending movement of the liquid trough the screw. Rather than rising counter-current to the downward flow of water for separation, fine oil droplets are entrained by the helical flow towards the upper portion of fine-separation chamber **50** where they are released
25 through apertures **57**.

[0056] Furthermore, liquid flowing along the surface of screw **53** impinges upon the surface of screw **53**. This fluid impingement facilitates contact between oil droplets and the surface of screw **53**. As a result, small oil droplets cling to screw **53** and are removed from the stream. Coalescence between adjacent oil droplets causes formation of larger droplets, which are then entrained by the flow and left in the vicinity of apertures **57** for migration to oil collection zone **111**. Fines that could not be retained in collection zone **40** are removed at the bottom of screw nearby slots **58** which then discharge fines into collection zone **42**.

[0057] The flow is then directed to the lower portion of coalescing chamber **54** entering said chamber through the perforations of plate **54a**. Water flowing upwards agitates the free-moving beads enhancing both the coalescing effect and the self-cleaning process of the beads. As a result, oil droplets adhering to adjacent beads are readily brought together, forming larger drops that overcome the force of attraction exerted by the beads. Furthermore, the rubbing action occurring between the beads assist the release of oil droplets from the beads. Oil droplets thus removed from the stream migrate upwards being released through the perforation of plate **54b** into the upper portion of fine-separation chamber **50**. Nearby slots **57** allow the oil droplets to migrate into oil collection zone **112** and join the oil pad accumulated in vessel **10**.

[0058] The process of fine separation described above is repeated within screw **55** and coalescing chamber **56**, with oil and solids being directed to oil and solids collection zones **112** and **43**, respectively.

Water containing minute amounts of oil enters polishing chamber **70** through the upper perforated section of plate **56b** of coalescing chamber **56**. Some oil droplets coalesced in chamber **56** migrate into polishing chamber **70** and rise towards the upper section of polishing chamber **70**
5 from where they can be removed via conduit **94**.

[0059] The flow is diverted towards the lower section of polishing device **80** and enters said device for final separation. Remaining fines are deposited in area **44** at the lower part of coalescing chamber **82**.
10 Coalescing zone **82a** achieves removal of minute droplets of oil. In coalescing zone **82a**, oil droplets flow through fine coalescing beads designed to significantly hinder the passage of oil droplets. The beads are electro-statically charged to enhance the attraction of oil particles by said beads. The force of attraction exerted by the beads retains minute oil
15 particles within the coalescing zone **82a**. A process of gradual coalescence taking place in zone **82a** forms a film of oil at the upper section of said zone in the vicinity of perforated plate **85**. The flow of water exiting zone **82a** through plate **85** shears off the oil film and larger oil droplets reach coalescing zone **82b** where they are subject to further
20 coalescence by the coarse beads moving freely in said zone.

[0060] Water containing relatively large oil droplets resulting from zone **82b** flows upwards and exits coalescing chamber **82** through screen **86**. A crescent-shaped space extends along and above coalescing
25 chamber **82**. Upon exiting coalescing chamber **82**, water travels upwards assisting the migration of oil drops to collection zone **80b**. Oil in collection zone **80b** exits apparatus **200** by means of conduit **76**. The

crescent shaped space above coalescing chamber **82** curves the path of the water and the flow is diverted smoothly downwards in a fashion that prevents the formation of undue eddies that could entrain oil droplets into the effluent.

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[0061] The design of the polishing device **80** ensures that the cross sectional area of the open space in the way of perforated stiffeners **87** is greater than the cross sectional area of perforated plate **86**. As a result, the velocity of water leaving coalescing chamber **82** is greater than the
10 velocity of the water moving downwards in the vicinity of stiffeners **87**. The flow of water towards the outlet **75a** is therefore achieved with minimal probability of carry over of oil droplets. As shown above, the curved surface of the coalescing chamber **82** virtually eliminates eddies and thus further prevents undue contamination of the effluent.

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[0062] Furthermore, the novel design of the exit space causes acceleration of the liquid flow towards the corners of the exit space at considerable distance from the oil droplets exiting coalescing chamber **82**. Thus, the oil droplets are able to move upwards in the mid section of
20 the crescent, or moon-shaped, exit space without interference by the downward flow of water. Virtually oil-free water enters chamber **75c** and then exits polishing chamber **80** through outlet line **75a**. Oil separated within corrugated plates pack **30** enters collection zone **110** forming a pad. The upper section of the oil pad floats above the water contained
25 within vessel **10** and migrates toward baffle **61**. Oil passes over the edge of baffle **61** and then over baffle **62** spreading uniformly throughout oil collection zones **111** and **112** being rendered drier and cleaner. This is

due to the fact that water droplets contained in the oil pad find it difficult to overcome gravity and follow the oil in an upwardly movement as the oil passes over the edges of baffles **61** and **62**.

5 **[0063]** Oil reclaimed within fine-separation chamber **50** escapes through slots **57** and joins the oil pad in oil collection zone **111** and zone **112**. Because the oil pad is separated from the flow of water by the walls of fine-separation chamber **50**, oil droplets that need more time to be absorbed by the oil pad are not carried over towards the exit.

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[0064] Apparatus **200** may be operated automatically using any suitable control system. Such control systems are well known to those skilled in the art and will not be described here in detail. The following explains briefly the operation of a possible control system for apparatus
15 **200**. Oil accumulated in the collection zones is monitored by means of an oil probe (not shown) which may be a conductivity-type oil sensor. The oil probe may be installed in conduit **93**. As the oil-water interface moves downwards, the oil probe initiates an oil discharge sequence at a preset level. A valve (not shown) which may be mounted on conduit **92** is then
20 opened automatically and oil is evacuated through the valve. This causes the oil-water interface to move upwards. When the oil probe detects that the oil water interface has dropped to a higher threshold level, the oil discharge sequence is stopped by closing the valve.

25 **[0065]** Liquid level in vessel **10** is preferably monitored by a level sensor (not shown). The level sensor may be mounted on conduit **90** to monitor the interface between the oil pad and the water, and provides a

signal to activate another valve downstream in conduit 75a when the level of this interface exceeds or drops below preset levels.

[0066] Apparatus according to the invention may be made using
5 any suitable construction techniques. For example, parts may be affixed to one another by welding, bolting, riveting, or other suitable techniques applicable to the materials used being. The choice of construction techniques and the choices of materials used in making apparatus according to the inventions disclosed herein are matters of design
10 convenience.

[0067] Where a component (e.g. a component, assembly, device, circuit, etc.) is referred to above, unless otherwise indicated, reference to that component (including a reference to a "means") should be
15 interpreted as including, as equivalents of that component, any component which performs the function of the described component (i.e., that is functionally equivalent), including components which are not structurally equivalent to the disclosed structure which performs the function in the illustrated exemplary embodiments of the invention.

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[0068] Apparatus according to some aspects of the invention have subsets of the features described above. For example, the invention provides:

- apparatus having a fine separation stage having some or all of the
25 features described above;
- apparatus having a polishing stage housing some or all of the features described above;

- apparatus having a plates pack oriented as described herein; and,
- so on.

The invention encompasses apparatus and methods comprising any novel and inventive features; novel and inventive combinations of features or
5 novel and inventive sub-combinations of features described herein.

[0069] As will be apparent to those skilled in the art in the light of the foregoing disclosure, many alterations and modifications are possible in the practice of this invention without departing from the spirit or scope
10 thereof. For example, Figure 2 shows a plates pack 30 inclined at an angle of 60° to the horizontal. This angle does not need to be exactly 60° but could be any angle in a suitable range around 60°. The range may begin, for example, at 45°, 50°, 55° or 59° and may extend, for example, to 61°, 65°, 70° or 75°.

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[0070] Accordingly, the scope of the invention is to be construed in accordance with the substance defined by the following claims.